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TITLE OF INVENTION
Vacuum Ultraviolet Applications with Blue Phosphor

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ENCLOSED APPLICATION PARTS

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Vacuum Ultraviolet Applications with Blue Phosphor

BACKGROUND OF THE INVENTION

This invention relates to blue-emitting phosphors and mixtures thereof for use in plasma display devices or other VUV excited devices. These devices include, in part, such apparatus as a plasma display panel or vacuum ultraviolet excited lamp which consist in part of a sealed transparent structure filled with a rare or noble gas or mixture of such rare or noble gases and also containing red-, green-, or blue-emitting phosphors. The gas is excited by a high voltage electrical current and emits high energy ultraviolet radiation, which then excites the phosphors to emit visible light.

Conventional plasma display devices are filled with rare gases or mixtures of rare gases such as helium, neon, xenon, and krypton, which are excited by a high voltage electrical current and emit ultraviolet radiation in the VUV range below 200 nm wavelength. This emitted VUV radiation is then used to excite various blue, green, and red emitting phosphors. The plasma display panels are made with a back carrier plate, a transparent front plate, and a ribbed structure, which divides the space between the front and back plates into cells. The plasma display panels also contain a sophisticated electrode array, which can address and excite each discrete plasma cell individually. Each cell contains a small amount of the rare gas mixture and a small quantity of phosphor, which emits only one of the three colors. Cells containing phosphors which emit with each of the three distinct colors, red, green, and blue, are statistically distributed on the back plate within the panel in much the same fashion as the different colored pixels are distributed in other types of display panels, such as CRT displays. VUV lamps also contain rare gases or mixtures of rare gases and phosphors, which emit in the three different colors. VUV lamps are similar to display panels in the excitation-emission principles except that blends of blue, green, and red phosphors are coated on the inside of a lamp and emit with an overall white color instead of the three separate colors which are emitted by the various discrete plasma cells.

These phosphors differ from those typically used in conventional fluorescent lamps in that they are excited by high energy vacuum ultraviolet photons with wavelengths less than 200 nm while the conventional fluorescent lamp excitation energy is primarily the lower energy 254 nm emission from mercury vapor. Currently, the most common VUV excitation energy comes from xenon or xenon-helium plasmas, which emit in the region 147 nm to 173 nm, with the exact emission spectra depending on the Xe concentration and overall gas composition. Under high voltage excitation, Xe-based plasmas typically have a Xe emission line at 147 nm and a Xe eximer band emission around 173 nm.

The large difference in excitation energies between vacuum ultraviolet and conventional short-wave ultraviolet fluorescent applications impose new requirements on the phosphors used for VUV display panels or lamps. Furthermore, differences in the manufacturing processes used for VUV and conventional fluorescent devices also impose new requirements on the phosphors.

In general, the VUV excited phosphors used to emit all three colors (red, green, and blue), exhibit some undesirable properties, but the phosphor most commonly used as the blue emitter, $Ba_{1-x}Eu_xMgAl_{10}O_{17}$ [$0.01 < x < 0.20$] or BAM, is most problematic. This phosphor is known to degrade in both brightness and color during the manufacturing process due to elevated temperatures and humidity. During manufacture of PDP panels, a thin MgO layer is applied for the purpose of protecting the transparent front plate and dielectric layer. MgO is quite hygroscopic and the high humidity conditions found during manufacture of the panels arise from water that is dissociated from the MgO layer during bakeout. This water is believed to be instrumental in the degradation in color causing a shift in the color point towards the green region. This phosphor also degrades in both brightness and color after extended exposure to the high intensity Xe plasma and VUV photon flux. Degradation mechanisms of BAM are the subject of much study and are thought to involve such changes as oxidation of Eu^{2+} to Eu^{3+}, modifications in the actual structure of the aluminate phosphor lattice, and movement of the Eu^{2+} activator ions between different sites within the lattice. The actual life of a commercial plasma display panel is dramatically shortened due to the shift in color point and intensity reduction of the blue phosphor component, which leads to an undesirable yellow shift in the overall panel color. One highly relevant measure of this degradation is the maintenance of the intensity / CIE y color point which can be calculated as a percentage. Both the intensity decrease due to degradation and the increase in CIE y color coordinate caused by a shift toward green in the color point result in a reduction of the I / y ratio.

In recent years, a number of different approaches have been attempted in order to improve the maintenance of blue VUV excited BAM phosphors. These approaches include sol-gel coating of wide bandgap metal oxides onto BAM phosphor, U.S. Patent Application US 2002/0039665; thermal treatments of aluminate phosphors mixed with ammonium fluorides, U.S. Patent 6,242,043; and solution based catena-polyphosphate coatings of BAM phosphor, U.S. Patent 5,998,047. Substitutional variations of the BAM stoichiometry have also been attempted in order to improve the maintenance of BAM such as substitution of alkali metals, alkaline earth metals, or zinc for one or more of the metallic components in BAM, U.S. Patent Application US 2002/0190240 A1. To date, none of these approaches have been entirely successful. A solid solution phase of BAM-Ba hexa-aluminate ($0.82BaO \cdot 6Al_2O_3$) exhibits improved color stability and maintenance but has an undesirable color point.

In addition, new phosphor compositions have been investigated which exhibit improved maintenance relative to commercial BAM phosphors such as $(La_{1-x-y-z}Tm_xLi_ySr_z)PO_4$, U.S. Patent 5,989,454; $Ba_{1-a}Eu_aMgAl_6O_{11}$, U.S. Patent 6,527,978; $CaMgSi_2O_6:Eu^{2+}$; and $CaAl_2O_4:Eu^{2+}$. New mixtures or blends of blue VUV phosphors have also been disclosed with improved maintenance characteristics such as $(La_{1-x-y-z}Tm_xLi_yAE_z)PO_4$ mixed with BAM, Eu^{2+}-activated barium magnesium lanthanum aluminate, Eu^{2+}-activated alkaline earth chloro apatite, or Eu^{2+}-activated calcium chloro borate phosphors, U.S. Patent 6,187,225; and BAM or SCAP $(Ba,Sr,Ca)_5(PO_4)_3Cl:Eu$ mixed with a wide number of UV-C light emitting phosphors, U.S. Patent Application US 2001/0033133 A1.

Although many of these phosphors or phosphor complexes exhibit improvements in color and intensity stability, none have proven to be viable alternatives to the commercial standard blue VUV activated phosphor BAM. Thus, there is still a commercial need for improved blue VUV activated phosphors with reduced degradation characteristics. A desirable phosphor would have the following properties: a deeper blue color, improved color stability during panel manufacture, improved lifetime during panel operation, and a high relative percent maintenance of the intensity / CIE y color point after accelerated thermal, humidity, Xe plasma, and high intensity VUV photon flux testing.

DESCRIPTION OF THE INVENTION

Laboratory tests have been designed to simulate actual PDP panel manufacturing and use which include a thermal humidity test and an accelerated aging test. Brightness before and after the thermal humidity and accelerated aging tests were obtained by measuring emission spectra using a Perkin-Elmer LS-50B spectrometer and quantifying them relative to the emission spectrum of a standard BAM phosphor reference. The peak wavelengths at maximum intensity were derived from the spectra and the y coordinate color values were calculated from the spectral data using well-known and accepted equations based on X, Y, Z – tristimulus curves. The excitation source is a commercially available xenon excimer lamp (XeCM-L from Resonance, Ltd., Barrie, Ontario, Canada) used to illuminate powder plaques while excluding air from the VUV beam path. The phosphor can also be mixed into a paste, coated onto alumina chips or "slides" and dried, and measured in this fashion.

The thermal humidity test involves exposing blue PDP phosphor samples to a warm water saturated air flow at 425 °C for 2 hours. The accelerated aging test involves exposure to a high intensity Xe plasma and VUV photon flux. The accelerated aging test is performed using a high-power rare-gas discharge "torture chamber," dubbed the VURAAC. The VURAAC consists of a 100 cm loop of 5 cm I.D. Pyrex™ tube that has approximately 5 millitorr of flowing Xe after initially pumping down to a 10^{-6} torr vacuum. Other gases / combination of gases may also be used. An inductively coupled discharge is obtained after receiving approximately 280 watts of input power at 450 kHz from an RF power supply. It is estimated that there is approximately 90 milliwatts/cm^2 of 147 nm VUV radiation at the sample surface. No significant excimer emission is generated under these conditions. After a selected amount of time exposed to the Xe discharge, the samples were measured for brightness as described above.

Limited plasma panel results indicate that such laboratory tests do indeed simulate actual PDP panel manufacturing and usage conditions.

One of the VUV excited blue-emitting phosphor components disclosed herein is europium-activated calcium-substituted barium hexa-aluminate, $Ba_{1.29-x-y}Ca_xEu_yAl_{12}O_{19.29}$, [with $0 < x < 0.25$, $0.01 < y < 0.20$] previously described as a conventional fluorescent phosphor in U.S. Patent No. 4,827,187, and hereto forward described by the acronym CBAL.

This CBAL material has a deeper blue emission peak but with only 80 – 85% the initial intensity of a commercially available BAM blue VUV activated phosphor. However, upon exposure to elevated temperature and humidity conditions, this material exhibits very nearly zero green shift in the color point and very little loss of intensity. Furthermore, upon exposure to a high intensity VUV photon flux used as an accelerated aging test, this material exhibits less than ½ the intensity degradation found in a commercial BAM phosphor and very nearly no color shift.

Furthermore, CBAL, europium-activated calcium-substituted barium hexa-aluminate, can be coated with an aluminum oxyhydroxide coating while in a fluidized bed reactor resulting in additional improvements to its maintenance when exposed to the high intensity VUV photon flux. This material will be further described by the acronym cCBAL.

Another component used in the VUV phosphor mixtures of this invention is the conventional and commercially available phosphor, $Ba_{1-x}Eu_xMgAl_{10}O_{17}$ [$0.01 < x < 0.20$], known as BAM. This material as a component by itself, and as described previously, exhibits an unacceptable large color shift and loss of intensity upon exposure to elevated temperatures, high humidity, and high intensity Xe plasma and VUV photon flux. However, BAM can be coated with an aluminum oxyhydroxide coating while in a fluidized bed reactor. This material exhibits much lower intensity degradation upon exposure to high intensity VUV photon flux than does the typical and commercially available BAM component. This material is denoted cBAM.

Another component of VUV phosphor mixtures of this invention is $(Gd,La)PO_4$:Tm,Li, a near-UV, blue, and IR emitting phosphor previously disclosed in U.S. Patent Nos. 6,187,225; 5,989,454; and 6,419,852. This material also exhibits very little color shift and loss of intensity upon exposure to elevated temperatures, high humidity, and high intensity Xe plasma and VUV photon flux and will be further denoted LaPOT.

CBAL, cCBAL, and cBAM, all exhibit or are expected to exhibit improved intensity and color stability when measured as powders under laboratory test conditions designed to simulate plasma panel conditions. Mixtures of CBAL – BAM, cCBAL-LaPOT, and CBAL-LaPOT also show improved intensity maintenance and color stability in comparison to commercially available BAM when tested in the laboratory.

<u>Examples</u>

CBAL can be made by thoroughly blending aluminum hydroxide, barium carbonate, calcium carbonate, europium oxide, and barium fluoride or boric acid and then firing the resulting mixture in alumina or alumina-based trays for between 2 and 4 hours in a reducing furnace under a nitrogen-hydrogen atmosphere (ranging from 5% hydrogen to 75% hydrogen with the remainder being nitrogen gas) at temperatures from 1400 °C to 1600 °C. The fired cakes are then washed in de-ionized water and wet sieved through a 378 mesh screen or alternatively lightly milled before wet sieving 378 mesh. The material is then dried and dry screened through a 60 mesh sieve to break up any possible

[redacted]

agglomerates. Three non-limiting examples of CBAL formulations are listed below with the first formulation used to prepare samples discussed in the following results section. Formulation variations can be used to prepare similar material with similar properties.

CBAL Formulation #1

Reagent	molar ratio	wt. Ratio (adjusted by assay)
$Al(OH)_3$	11.0000	6.9076
$CaCO_3$	0.1700	0.1366
BaF_2	0.1000	0.1407
Eu_2O_3	0.0400	0.1153
$BaCO_3$	0.8325	1.3251

CBAL Formulation #2

Reagent	molar ratio	wt. Ratio (adjusted by assay)
$Al(OH)_3$	11.0000	3.3458
$CaCO_3$	0.1500	0.0602
BaF_2	0.1000	0.0704
Eu_2O_3	0.0400	0.0576
$BaCO_3$	0.8525	0.6785

CBAL Formulation #3

Reagent	molar ratio	wt. Ratio (adjusted by assay)
$Al(OH)_3$	11.0000	3.443
$CaCO_3$	0.1000	0.040
H_3BO_3	0.20 wt%	0.009
Eu_2O_3	0.0400	0.056
$BaCO_3$	1.003	0.794

The preparation of BAM and LaPOT phosphors followed traditional solid state techniques and will not be described in detail. The procedure for applying an aluminum oxyhydroxide coating to BAM and/or CBAL forming cCBAL and cBAM is described in a copending provisional application filed May 15, 2003 and having attorney docket no. 03-2-311 (Fan et al.) and is incorporated herein by reference.

The blend of CBAL and BAM discussed in this document was prepared by adding equal amounts of the two components to a clean glass container and then thoroughly mixing them through the roll-blending technique. Such mixtures can easily be modified to give the desired properties by adjusting the weight ratios of the two components. Typically, the ratios of the two components will range from between 1:20 to 20:1 by weight. Other types of containers and blending techniques can be used as well.

The blend of CBAL and cBAM discussed in this document was prepared in the same fashion by adding equal amounts of the two components to a clean glass container and then thoroughly mixing them through the roll-blending technique. As mentioned above, such mixtures can easily be modified to give the desired properties by adjusting the

weight ratios of the two components. Typically, the ratios of the two components will range from between 1:20 to 20:1 by weight. Other types of containers and blending techniques can be used as well.

Blends of CBAL - LaPOT and cCBAL – LaPOT were prepared by physical mixing techniques which can include but are not limited to adding specified quantities of the two components to glass containers along with a small amount of media and de-ionized water and thoroughly mixing the material by roll-blending for 20 minutes. The media were removed and the samples were dried before testing. Three non-limiting CBAL:LaPOT ratios used were 2:1, 5:1, and 11:1 by weight. The 2:1 mixture exhibited small emission peaks in the UV region due to the Tm^{3+} emission from the LaPOT component. As stated before, such mixtures can easily be modified to give the desired properties by adjusting the weight ratios of the two components. Typically, the ratios of the CBAL:LaPOT components will range from between 1:20 to 20:1 by weight, but more preferentially ranging between 2:1 to 20:1 by weight. Other types of containers and blending techniques can obviously be used as well.

Results:

Samples of CBAL, cCBAL, cBAM, CBAL/BAM mixtures, CBAL/cBAM mixtures, CBAL/LaPOT mixtures, and cCBAL/LaPOT mixtures were prepared as described above. These samples along with a sample of BAM (a commercially available phosphor used as the control) were then measured for initial intensity relative to a standard and the VUV emission spectra were collected using the Perkin-Elmer LS-50B spectrometer previously described. The samples were then degraded through the thermal-humidity treatment previously described and the VUV intensity was measured again and the VUV emission spectra collected. All samples were degraded under experimentally equivalent conditions. The same samples were further degraded through exposure to high intensity Xe plasma and VUV photon flux using the VURAAC apparatus previously described. Again, the VUV intensity was measured for these samples and the VUV emission spectra collected. It is thought that these accelerated degradation test closely mimic conditions found in PDP panel manufacture and use. Furthermore, it is thought that the results are relevant for comparison with the degradation found during manufacture and use of any VUV excited device. Results from these tests are listed below in Tables 1 and 2.

Table 1. Powder Plaque Optical Emission Results from Initial and Degraded Blue VUV Excited Phosphors [TH = degraded due to elevated temperature and humidity; THX = degraded due to elevated temperature and humidity followed by high intensity Xe plasma and VUV photon flux] / Intensity is Measured Relative to a Standard Blue PDP BAM Phosphor

Powder Plaque Data							
	BAM control #1	CBAL #1	cBAM	CBAL - BAM mixture	CBAL - cBAM mixture	CBAL - LaPOT mixture #1	CBAL - LaPOT mixture #2
Intensity (initial)	96%	80%	82%	87%	81%	75%	77%
Peak λ (initial)	447 nm	440 nm	448 nm	444 nm	444 nm	440 nm	440 nm
Initial y value	0.0466	0.0552	0.0476	0.0505	0.0508	0.0588	0.0582
Intensity (TH)	88%	76%	79%	81%	76%	72%	74%
Peak λ (TH)	458 nm	440 nm	456 nm	449 nm	448 nm	440 nm	440 nm
(TH) y value	0.0852	0.0564	0.0806	0.0719	0.0701	0.0581	0.0575
% I / y (TH)	50%	93%	57%	65%	68%	96%	98%
Intensity (THX)	52%	48%	57%	49%	49%	46%	48%
Peak λ (THX)	456 nm	440 nm	455 nm	447 nm	448 nm	440 nm	440 nm
(THX) y value	0.0931	0.0632	0.0912	0.0759	0.0785	0.0675	0.0668
% I / y (THX)	27%	53%	36%	37%	40%	54%	55%

Although the BAM control#1 sample exhibits the greatest initial intensity, it also exhibits the worst degradation as measured by the % I / y ratio. The I / y ratio after thermal-humidity testing is only 50% of the initial I / y ratio for the BAM control#1 and 27% of the initial I / y ratio after thermal-humidity and high intensity Xe plasma – VUV photon flux testing. Its final intensity (THX) is at most 6% higher than the least intense sample while initially the BAM control was as much as 16% higher than the least intense sample.

All of the experimental samples exhibit significantly better maintenance of the I / y ratio than does the BAM control. In particular, the CBAL#1 and CBAL-LaPOT mixtures #1 and #2 exhibit superior maintenance of the I / y ratio after degradation testing. The (TH) samples are more than 80% better than BAM, maintaining > 93% of the initial I / y ratio after thermal humidity testing (vs. 50% for the control) and the (THX) samples are nearly 100% better than BAM, maintaining > 53% of the initial I / ratio after thermal-humidity and high intensity Xe plasma – VUV photon flux testing (vs. 27% for the control). In addition, all samples except cBAM have a bluer initial peak than does the BAM control as evidenced through the initial peak wavelength listed in the Table 1. All samples, including cBAM, have bluer emission peaks after both (TH) and (THX) degradation treatments than the BAM control. In the worst case, the cBAM sample maintains only 36% of its initial I / y ratio after (THX) degradation but that is 1/3 better than the BAM control's 27 % I / y ratio maintenance. The CBAL-BAM and CBAL-cBAM mixtures show degradation maintenance midway between the high levels found for CBAL and CBAL-LaPOT mixtures and the medium level found for cBAM.

Table 2. Powder Plaque and Paste Slide Optical Emission Results from Initial and Degraded Blue VUV Excited Phosphors [TH = degraded due to elevated temperature and humidity; X = degraded by high intensity Xe plasma and VUV photon flux; THX = degraded due to elevated temperature and humidity followed by high intensity Xe plasma and VUV photon flux] / Intensity is Measured Relative to a Standard Blue PDP BAM Phosphor

	Powder Plaque Data			Paste Slide Data				
	BAM control #2	Uncoated CBAL #2	Coated cCBAL	BAM control #2	Uncoated CBAL #2	Coated cCBAL	CBAL-LaPOT #3	cCBAL-LaPOT
Intensity (initial)	96%	76%	68%	104%	84%	79%	84%	77%
Peak λ (initial)	446 nm	439 nm	439 nm	446 nm	439 nm	439 nm	439 nm	439 nm
Initial y value	0.0465	0.0568	0.0553	0.0466	0.0518	0.0517	0.0518	0.0523
Intensity (TH)	87%	74%	69%	96%	82%	79%	79%	77%
Peak λ (TH)	456 nm	439 nm	439 nm	456 nm	439 nm	439 nm	439 nm	439 nm
(TH) y value	0.0803	0.0571	0.0566	0.0771	0.0527	0.0542	0.0535	0.0546
% I / y (TH)	52%	96%	98%	56%	96%	95%	91%	96%
Intensity (X)	57%	42%	49%	76%	61%	66%	67%	69%
Peak λ (X)	446 nm	439 nm	439 nm	446 nm	439 nm	439 nm	439 nm	439 nm
(X) y value	0.0527	0.0625	0.0608	0.0504	0.0565	0.0563	0.0573	0.0568
% I / y (X)	53%	50%	65%	68%	66%	76%	72%	82%
Intensity (THX)	52%	47%	49%	64%	60%	65%	63%	63%
Peak λ (THX)	454 nm	439 nm	439 nm	454 nm	439 nm	439 nm	439 nm	439 nm
(THX) y value	0.0901	0.0642	0.0633	0.0905	0.0596	0.0602	0.0602	0.0606
% I / y (THX)	28%	54%	63%	32%	62%	70%	65%	70%

The degradation results from powder and paste preparations of the same samples are basically equivalent. Although the paste brightness results tend to be higher than the powder brightness values, they are relatively the same. The peak wavelength at maximum intensity does not change for either the CBAL#2 or cCBAL samples while the BAM control#2 sample shows a large shift in color after the thermal humidity test. The initial brightness for the BAM control is much higher than the initial brightness of the CBAL, cCBAL, CBAL-LaPOT, and cCBAL-LaPOT samples, while after exposure to the thermal humidity test and the high intensity Xe plasma and VUV photon flux, all samples have comparable brightness. The maintenance of % I / y (Intensity / y) for the CBAL sample after (THX) thermal humidity and Xe plasma testing is vastly superior to that of the BAM control [54% vs 28% and 62% vs 32%] and the maintenance of coated CBAL (cCBAL) is further superior to that of uncoated CBAL [63% vs 54% and 70% vs 62%]. The coated cCBAL material also exhibits significantly improved maintenance after high intensity Xe plasma and VUV photon flux exposure without any thermal humidity tests being involved. The CBAL-LaPOT and cCBAL-LaPOT blends behave similarly to the CBAL and cCBAL components, but show higher maintenance values.

Figures:

Figure 1 graphically depicts the difference in (TH) degradation between CBAL and the BAM control samples. The CBAL material exhibits only a small loss of intensity with no apparent color shift while the BAM control exhibits a severe intensity loss and a dramatic color shift towards green. At this point, the integrated intensity of the (TH) treated CBAL sample begins to approach the integrated intensity of the (TH) treated BAM control. Figure 2 graphically depicts the additional degradation caused by the additional high intensity Xe plasma and VUV photon flux exposure of both samples. Both samples, CBAL and BAM, show a significant loss of intensity but the BAM control shows a much greater intensity loss. The (THX) treated CBAL sample exhibits no apparent color shift while the (THX) treated BAM control exhibits an undesirable color shift. The maximal peak intensity of the CBAL sample is equivalent to the maximal peak intensity of the BAM control, but the integrated intensity of the CBAL material is less than that of the BAM control due to the peak broadening and color shift of the BAM control.

Claims:

1) A PDP panel or other VUV excited device using CBAL, europium activated calcium substituted barium hexa-aluminate, $Ba_{1.29-x-y}Ca_xEu_yAl_{12}O_{19.29}$, [with $0 < x < 0.25$, $0.01 < y < 0.20$], as the blue phosphor component exhibiting improved degradation characteristics, reduced color shift, and reduced loss of intensity upon exposure to high intensity Xe plasma or other rare gas plasma and VUV photon flux.

2) A PDP panel or other VUV excited device using cCBAL, aluminum oxyhydroxide coated CBAL, as the blue phosphor component exhibiting improved degradation characteristics, reduced color shift, and reduced loss of intensity upon exposure to high intensity Xe plasma or other rare gas plasma and VUV photon flux.

3) A PDP panel or other VUV excited device using cBAM, aluminum oxyhydroxide coated BAM, $Ba_{1-x}Eu_xMgAl_{10}O_{17}$ [$0.01 < x < 0.20$], as the blue phosphor component exhibiting improved degradation characteristics, reduced color shift, and reduced loss of intensity upon exposure to high intensity Xe plasma or other rare gas plasma and VUV photon flux.

4) A PDP panel or other VUV excited device using a mixture of 2 or more of the blue phosphor components described in claims 1, 2, or 3 exhibiting improved degradation characteristics, reduced color shift, and reduced loss of intensity upon exposure to high intensity Xe plasma or other rare gas plasma and VUV photon flux. The amount of each phosphor component in this mixture can vary in the range from a minimum 5 weight % to a maximum 95 weight % of the total mixture.

5) A PDP panel or other VUV excited device using a mixture of 1 or more of the blue phosphor components described in claims 1, 2, or 3 with BAM, $Ba_{1-x}Eu_xMgAl_{10}O_{17}$ [$0.01 < x < 0.20$], exhibiting improved degradation characteristics, reduced color shift, and reduced loss of intensity upon exposure to high intensity Xe plasma or other rare gas plasma and VUV photon flux. The amount of each phosphor component in this mixture can vary in the range from a minimum 5 weight % to a maximum 95 weight % of the total mixture.

6) A PDP panel or other VUV excited device using a mixture of 1 or more of the blue phosphor components described in claims 1, 2, or 3 with LaPOT, $(Gd,La)PO_4$:Tm,Li, exhibiting improved degradation characteristics, reduced color shift, and reduced loss of intensity upon exposure to high intensity Xe plasma or other rare gas plasma and VUV photon flux. The amount of each phosphor component in this mixture can vary in the range from a minimum 5 weight % to a maximum 95 weight % of the total mixture

7) A PDP panel or other VUV excited device using a mixture of 1 or more of the blue phosphor components described in claims 1, 2, or 3 with both BAM, $Ba_{1-x}Eu_xMgAl_{10}O_{17}$ [$0.01 < x < 0.20$], and LaPOT, $(Gd,La)PO_4$:Tm,Li, exhibiting improved degradation characteristics, reduced color shift, and reduced loss of intensity upon exposure to high intensity Xe plasma or other rare gas plasma and VUV photon flux. The amount of each phosphor component in this mixture can vary in the range from a minimum 5 weight % to a maximum 90 weight % of the total mixture.

Vacuum Ultraviolet Applications with Blue Phosphor

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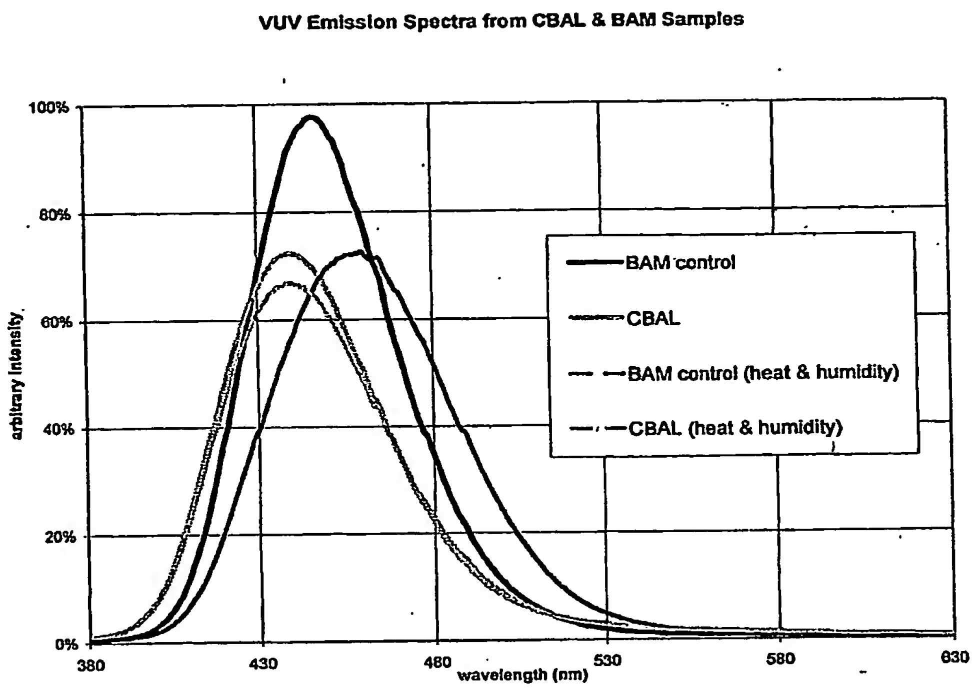
Abstract

Blue-emitting phosphors for use with plasma display panels (PDP) or other vacuum ultraviolet excited (VUV) devices are provided. These blue-emitting phosphors and mixtures thereof include at least one of the following: CBAL, europium activated calcium substituted barium hexa-aluminate, $Ba_{1.29-x-y}Ca_xEu_yAl_{12}O_{19.29}$, [with $0 < x < 0.25$, $0.01 < y < 0.20$]; BAM, $Ba_{1-x}Eu_xMgAl_{10}O_{17}$ [$0.01 < x < 0.20$]; cBAM, aluminum oxyhydroxide coated BAM, $Ba_{1-x}Eu_xMgAl_{10}O_{17}$ [$0.01 < x < 0.20$]; cCBAL, aluminum oxyhydroxide coated CBAL, europium activated calcium substituted barium hexa-aluminate, $Ba_{1.29-x-y}Ca_xEu_yAl_{12}O_{19.29}$, [with $0 < x < 0.25$, $0.01 < y < 0.20$]; and LaPOT, $(Gd,La)PO_4$:Tm,Li. A PDP panel or other VUV excited device using these blue-emitting phosphors or mixtures thereof exhibit improved degradation characteristics. These improved degradation characteristics include reduced color shift and increased intensity maintenance. Moreover, the reduced color shift and reduced loss of intensity are measured under elevated thermal and humidity conditions, high intensity Xe plasma or other rare gas plasma, and high intensity VUV photon flux.

Figure 1. **Initial and Degraded (Elevated Thermal and Humidity Conditions) VUV Emission Spectra from CBAL and BAM (control) Samples**



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<u>Figure 2.</u> Initial and Degraded (Elevated Thermal and Humidity Treatment Followed by Accelerated Aging Treatment under High Intensity Xe Plasma and VUV Photon Flux) VUV Emission Spectra from CBAL and BAM (control) Samples.